USGS

WATER RESOURCES RESEARCH GRANT PROPOSAL

Title: Restoration of Indiana Streams:A Comparison of Restoration Strategies at a Statewide Level

Focus Categories: ECL, SW, WQL

Keywords: Stream restoration, recovery, water quality, fish habitat, geomorphology

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Abstract

Land-use activities such as agriculture and urbanization have drastically modified the structure and function of streams and rivers globally (Allan 1995). Indiana is no exception to this trend. In the last century, rapid agricultural, commercial, and residential development in Indiana has contributed to surface water pollution, draining of wetlands, and stream channelization. Since the 1870's, Indiana has lost over 85% of its wetlands and land-use is now dominated by cropland (Dahl 1990, USDA 1992). All of these activities result in stream habitat losses and impairment of water uses such as drinking, fishing, and swimming. A critical need exists to restore habitat and water quality in midwestern streams, yet little information exists on effective restoration methods and appropriate monitoring criteria. The immature state of restoration ecology underscores the need for basic ecological research to refine current stream restoration practices.

In fall 1997, 1-km reaches in each of two channelized streams in Northwest Indiana were reconstructed by adding two meanders to each stream. Reconstructed reaches in Juday Creek (South Bend, IN) received major habitat improvements, bank stabilization, and silt removal. Potato Creek (North Liberty, IN) received little additional rehabilitation beyond the construction of meanders. Funding provided by the USGS, through a NIWR grant, has allowed us to evaluate both restorations for the past two years. With an IWRRC grant, we plan to assess both restorations for an additional year using physical, chemical

and biological criteria. In addition, we will conduct a survey of government agencies, non-governmental organizations, and private consulting firms in Indiana to determine stream restoration strategies being employed throughout the state. This information will place into perspective the restorations that we are intensively studying, and provide insight into statewide efforts to restore streams.

The two restorations we are currently studying, together with our statewide survey, will allow us to compare strategies and successes of stream restorations across the state. The major objectives of our study are to: (1) evaluate current restoration techniques for Indiana streams, (2) identify biological criteria potentially useful for evaluating the short-term success of other stream restoration projects in Indiana and other midwestern states, and (3) gather information on stream restoration efforts statewide, including restoration approaches, scale of efforts, and scope of pre- and post-restoration evaluation.

The Juday Creek and Potato Creek restorations are both attempting to reestablish contact between the stream channel and the riparian zone, as well as to restructure the channel to improve biological habitat. The proposed study seeks to address some of the deficiencies in stream restoration and evaluation by determining whether current techniques restore ecosystem structure and function. The proposed research will also determine whether restoration strategies used for Juday Creek and Potato Creek are representative of current statewide efforts, and if we can predict the success of restorations based on the type and scale of the approach.

Statement of Critical Problem

Since the late 1800's, streams and rivers in Indiana have been ditched, diverted, and straightened, and riparian habitats have been drastically modified, resulting in impaired water quality and loss of habitat for aquatic and riparian biota (NRC 1992). Nearly 41% of perennial streams in the United States are affected by siltation, bank erosion, and channelization (Council on Environmental Quality 1989), which have adversely affected biota in these streams, as well as reduced water quality for human uses. Although precise numbers for Indiana do not exist, the percentage of impacted streams in Indiana needing restoration is likely even higher. We do know that the majority of watersheds in Indiana have more than 5 aquatic or wetland species at risk of becoming locally extinct (EPA 1996). Although the need to repair degraded ecosystems is urgent, the field of restoration ecology is relatively young (NRC 1992) and little information exists on effective restoration strategies for streams and rivers in Indiana and other midwestern states. Current efforts to restore degraded streams demand basic ecological information. For many restoration attempts, long-term, quantitative data for restored and reference sites are lacking, and failed restoration attempts go unreported (NRC 1992).

A recent issue of *Science* (1999, vol. 286 no. 5448) predicted that river restoration would be one of the 7 scientific fields that will rise to prominence in the next decade. In addition, the National Research Council (1992) recommends that 400,000 stream and river miles be restored by approximately the year 2012. In order for restoration of streams in Indiana and other midwestern states to succeed, methods of stream restoration,

adequacy of monitoring programs, and the cost-effectiveness of current restoration practices need to be evaluated.

Statement of Results or Benefits

Many state and federal agencies in the U.S. have attempted habitat improvement for streams affected by anthropogenic disturbances. Projects have ranged from installation of in-stream structures, to revegetation of the riparian zone, addition of gravel to riffle habitats to encourage salmonid spawning, and fish stocking. Stream restoration is becoming a common practice in the western U.S., where streams are impacted by impoundments, logging, livestock grazing, and other practices (Mesick 1995), and in the Northeast, where streams are degraded by acid rain and urbanization (NRC 1992). However, restorations of midwestern streams are rare, and the few that are done are rarely evaluated beyond pure observation. The proposed research will address this glaring lack of information on midwestern stream restorations and create for Indiana a statewide inventory of current restorations.

We have collected pre- and post-restoration data on two northwestern Indiana streams for which reaches were restored in 1997. The restorations of Juday Creek (South Bend, IN) and Potato Creek (North Liberty, IN) involved differing degrees of geomorphic manipulation to enhance biological habitat, and represent two typical restoration techniques used for midwestern streams. With IWRRC support, we propose to quantify the response of stream structure and function to the restorations for an additional year, which should allow for a more thorough post-restoration evaluation of stream recovery. We will also conduct a comprehensive survey of government agencies (local, state, and federal), non-governmental organizations, and private consulting firms to assess present restoration efforts in Indiana. Data will be collected on important factors related to the restoration, including restoration techniques used, scale of the restoration, and type of evaluation employed. Results on stream recovery from the two restorations evaluated in northwestern Indiana, coupled with data from our statewide survey, can be used to assess the potential success of other Indiana restorations. Our results will also provide aquatic scientists and engineers with critical information needed to design and conduct successful restorations throughout the state.

Nature, Scope, and Objectives of the Research

The term "restoration" has had many different definitions assigned to it. It is frequently suggested that restoration means returning an ecosystem to its pre-disturbance state; however, in many situations this goal is practically impossible (NRC 1992). Many streams have been dramatically altered decades ago, and little or no information exists on their original condition, nor could historic conditions be recreated even if known. Rather than establishing unachievable restoration goals, restoration designs should focus on enhancing ecosystem structure and critical processes. Furthermore, pre- and post-restoration monitoring of ecosystem structure and processes should be a priority in order to assess the success of stream restorations. Because streams are longitudinally linked, an ecosystem approach can determine if the source of the problem is in the watershed,

riparian zone, reach, or a single habitat type. For example, high rates of erosion upstream could potentially negate any benefits brought about by the restoration downstream. Unfortunately, many stream restorations take a species-centered approach in design and monitoring, which is often focused on a sport fish (NRC 1992).

The proposed research will assess our current ability to understand and restore streams in Indiana, as a model for other areas of the Midwest, which will allow us to address critical questions such as: What mechanisms are responsible for successful and failed restorations? What is the status of stream restoration in Indiana? and What level of monitoring is appropriate for Indiana restorations? The specific objectives of the proposed research are to: (1) evaluate current restoration methods for Indiana streams, (2) identify biological criteria potentially useful for evaluating the short-term success of stream restoration projects in Indiana and neighboring states, and (3) assemble information on stream restorations statewide, including restoration approaches, scale of effort, and types of pre- and post-restoration evaluation.

Timeline

	W/SP '00	**SU'00**	**F '00**	**W/SP '01**
Field Measurements				
Juday Creek and Potato Creek	X	X	X	X
Statewide Survey	X	X	X	
Data Analysis	X	X	X	X
Report Preparation				X
Present at a Scientific Meeting				X

Methods, Procedures, and Facilities

Our basic experimental design for our two intensive sites (Juday Creek and Potato Creek) is to continue sampling physical, chemical, and biological variables as we have done for the past two years. Restored stream reaches will be compared to upstream, unrestored reaches in both streams. Pre-restoration data has been collected for both streams and post-restoration evaluation will continue for an additional year with support from IWRRC. A statistical approach, the Before-After-Control-Impact (BACI) approach, will be used to detect changes resulting from the restoration (Stewart-Oaten et al. 1986). Variables were chosen to assess both stream structure and function, and biological responses will be evaluated at the population, community, and ecosystem levels.

Physical Responses - Changes in channel morphology, riparian conditions, and in-stream features will be assessed by conducting an annual survey of habitat and large woody debris. Study reaches will be assessed by identifying stream units (riffle, run, or pool) based on standard criteria (Bisson and Montgomery 1996). For each unit, we will measure length and width at 2-3 cross sections to determine mean wetted and active channel width, and mean and maximum depth of the unit. Substrate composition and embeddedness, percent fish cover, dominant types of fish cover, riparian vegetation, and canopy will also be evaluated.

Short-term organic matter retention will be measured annually in each study reach as an index of habitat complexity and the retentive capacity of the stream. *Gingko* leaves and wood dowels will be used as tracers to mimic coarse particulate organic matter (Lamberti and Gregory 1996). Hydraulic retention (with conservative dye releases), suspended solids, temperature, pH, dissolved oxygen, and conductivity will also be measured in each study reach.

Biological Responses - Attached algae will be sampled using the most appropriate methods (e.g., cores or scrapes) for the representative substrates in each stream. Abundance will be measured as chlorophyll *a*, using the spectrophotometric method, and biomass will be determined as ash-free dry mass (Steinman and Lamberti 1996). At least three replicates per substrate type will be taken for each reach. Benthic macroinvertebrates are being studied by another graduate student at Notre Dame (J. Latimore), who will share information with our project.

Fish will be sampled in all study reaches using a Smith-Root Model 12 POW backpack electrofisher or by visual enumeration while snorkeling (Hankin and Reeves 1988). For electrofishing, a 60-m reach will be blocked off with nets and two or three sequential passes will be made through each site. Fish will be identified, enumerated, weighed, and measured for total length. For the visual estimates, a team of two divers will make fish counts while moving upstream. Divers will identify and estimate fish lengths throughout the entire study reach. Metrics including abundance, total biomass, species richness, functional composition of fish, length-frequency distributions, and Index of Biotic Integrity (IBI) will be determined for each reach (Simon 1997).

Statewide Survey - Information on present stream restorations in Indiana will be collected from local, state, and federal government agencies, non-governmental organizations, and private consulting firms. Location of the restoration, restoration techniques applied, scale of restoration (e.g., watershed, reach, single habitat type, with or without riparian restoration), responsible parties involved, and types of pre- and post-restoration evaluation of stream recovery will be gathered to assess the status of restorations statewide. We will visit representative restorations throughout the state and conduct a physical inventory of restored and unrestored reaches as described above. Time and workforce will not allow us to conduct biological sampling for the 5-10 restorations that we anticipate visiting. However, we will gather any biological information that exists for those sites, and if adequate biological information is available, we will quantify stream recovery using appropriate analyses such as those discussed above. Because statistics and compiled data on topics such as stream restoration are often hidden in grey literature, we plan to submit our results to be published in a peer-reviewed scientific journal. We will also post our results of the statewide survey on a website (http://www.nd.edu/~strmeco) that has been developed to keep the public informed of our ongoing stream restoration research. These attempts should make our statewide inventory on recent stream restorations more accessible to aquatic scientists in Indiana and neighboring states.

Related Research

Channel morphology, riparian conditions, and in-stream features all interact to provide habitat for stream biota. Therefore, changes in physical habitat variables and abundance of woody debris may alter habitat available for aquatic organisms. For example, fish abundance and distribution are influenced at a local scale by the combined effects of depth, current velocity, substrate particle size, cover, and temperature (Rabeni and Jacobson 1993). Stream alterations such as channelization alter many of these components and eliminate the natural pool-riffle pattern of a stream, which can affect the segregation of juvenile and adult fish (Jones 1975). Often the goal of stream restoration is to increase spatial heterogeneity in order to increase niche availability for biota. Many studies have demonstrated that structural variety of habitat leads to diverse aquatic communities (Sheldon 1968, Karr and Schlosser 1978, Dudley and Karr 1979, Tarplee et al. 1979, Meffe and Sheldon 1986). Jungwirth et al. (1995) found an increase from 10 to 16 species of fish one year following restoration of a channelized reach, while straightened reaches continued to contain 10 species. Three years later, species richness increased to 19 in the restored channel. They also found an increase in density and biomass of fish in a restored reach compared to a channelized section of the same stream.

Although a number of studies have evaluated stream recovery from various anthropogenic disturbances (see Niemi et al. 1990), research is lacking on recovery after restoration attempts at the community and ecosystem levels (Niemi et al. 1990, Detenbeck et al. 1992). We are unaware of any research that has evaluated midwestern stream restorations using an ecosystem-level approach. Our plan is to then apply the results to assess similar restorations throughout the state. In addition, we know of no inventory that has compiled information on statewide restoration practices for Indiana. Ashley Moerke, a graduate student at the University of Notre Dame, is conducting her

Master's thesis on the two stream restorations in northern Indiana (Juday and Potato Creeks). The major objectives of her thesis are to: (1) compare geomorphic, hydraulic, and biological features of restored and unrestored reaches, and before and after the restorations, with an emphasis on fish community response, (2) monitor persistence of habitat units and structures in the restored reaches, (3) identify biological criteria potentially useful for evaluating the short-term success of the restorations, and (4) compare the restorations to determine the more effective approach to restoring midwestern streams. Ms. Moerke plans to incorporate the proposed study into her Ph.D. research, which will commence in spring 2000.

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